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March 4, 2019

VIA ELECTRONIC FILING

Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
Office of the Secretary
445 12th Street, SW
Washington, DC 20554

Re: *Notice of Ex Parte Submission*
GN Docket No. 18-122

Dear Ms. Dortch:

Attached hereto is a Further Technical Statement that provides additional explanation for the technical rules proposed by the C-Band Alliance in its Comments and Reply Comments. Specifically, the Further Technical Statement addresses proposed rules and technical considerations designed to protect earth stations operating in the 3700-4200 MHz band from harmful interference caused by flexible use operations that would deploy at 3700-3880 MHz. The Further Technical Statement also provides a recommendation for implementing these rules in 47 CFR Part 27 and an example of application of the proposed rules. Finally, the Further Technical Statement addresses concerns and technical points raised in this proceeding by Comcast, NCTA, Ericsson, and AT&T.

Please contact the undersigned with any questions regarding this letter.

Respectfully submitted,

/s/ Jennifer D. Hindin
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Counsel for the C-Band Alliance

Attachment

Further Technical Statement

1. Technical Rules Proposed by the CBA to Protect Earth Stations Operating in the 3700-4200 MHz Band

In the Technical Annex to its Reply Comments, the CBA proposed technical rules to be adopted by the Commission in order to protect earth stations that will continue to receive satellite transmissions in the C-band downlink once terrestrial mobile operations have been introduced in a portion of the band.[1] Specifically, these rules will protect both earth stations that will operate in the 3900-4200 MHz band, as well as a few earth stations that will continue to operate in 3700-3900 MHz band at limited telemetry, tracking and control ("TT&C")/ingest sites.

This Further Technical Statement responds to incorrect assertions and assumptions made by parties in this proceeding regarding the CBA's proposed Fixed Satellite Service ("FSS") earth station protection rules. For example, although the CBA's proposed rules have some technical similarity with the Part 96 Citizens Broadband Radio Service rules, they do not require "some form of Spectrum Access System ('SAS')" as wrongly interpreted by AT&T.[2] These rules also do not require "extensive and ongoing reporting from earth station owners" nor do they impose "additional burden on terrestrial licensees possibly ultimately rendering the proposed transition unsustainable."[3]

Under the rules proposed by the CBA, the only earth stations eligible for the protection proposed by the CBA are those with a valid license to transmit that also includes the 3700-4200 MHz band, or a registration to receive satellite signals in the 3700-4200 MHz band filed no later than October 31, 2018 or filed during a short open filing period[4] to be established by the Commission. In order to accommodate exceptional situations, the CBA proposes that future FSS earth stations receiving in the 3900-4200 MHz band could only be registered and become eligible for protection pursuant to a waiver issued with the approval of all terrestrial operators licensed in the 3700-3880 MHz band ("Flexible Use Licensees") with a license for operation within 40 kilometers of the earth station location. As indicated in the CBA Reply Comments, a very limited number of earth stations will continue to receive in the 3700-3900 MHz band while all the other

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1 *See* Technical Annex, Reply Comments of the C-Band Alliance, GN Docket No. 18-122 (December 7, 2018) at 3 ("Reply Technical Annex").

2 *See* Reply Comments of AT&T Services, Inc., GN Docket No. 18-122 (December 11, 2018) at 24 ("AT&T Reply Comments").

3 *Id*. at 24-25.

4 This period is identified in proposed Section 27.78(a)(2).

earth stations will receive in the 3900-4200 MHz band.[5]

The CBA proposes that for each registered earth station eligible for protection, reception of C-band satellite signals will be protected for any antenna diameter between 3 meters and 13 meters, for any elevation angle greater than 5 degrees, anywhere within a 150-meter area surrounding the earth station location as registered.[6] It is important to note that the CBA proposal **does not** involve any dynamic reporting. The list of C-band sites to be protected will be fixed and limited additions will only be possible via waiver from the Commission with the agreement of the relevant Flexible Use Licensees, as described above.

In order to protect FSS earth station sites, each Flexible Use Licensee will have to ensure that it complies with the aggregate power density levels produced by its stations at existing FSS sites for in-band and out-of-band emissions. This will **not** require any SAS-like system because the calculations will be performed by the Flexible Use Licensees. If the calculations reflect that the limit would be exceeded, the Flexible Use Licensee will adjust the characteristics of its base or fixed station in order to ensure compliance. This can be achieved through a combination of options, such as selecting a specific antenna design, using mechanical or electric down-tilting, dynamic antenna pointing restrictions or power reduction. These engineering techniques are already being used by Flexible Use Licensees for the design and optimization of their existing radio networks and more sophisticated techniques are expected to be available for the deployment of 5G systems. Protection of FSS sites according to the CBA's proposed rules will only be one of the many parameters Flexible Use Licensees routinely will take into account when efficiently designing their 5G networks.

2. Proposed Rules to Ensure Protection of FSS Earth Stations

In order to implement the Market-Based Approach, the CBA recommends that the Commission amend 47 CFR Part 27 as follows:

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[5] In the Technical Annex to its Comments, the CBA identified a list of 14 FSS TT&C and ingest earth stations that will need to continue operating in the 3700-3900 MHz band and may require protection. *See* Technical Annex, Comments of the C-Band Alliance, GN Docket No. 18-122 (October 29, 2018) ("Comments Technical Annex"). The CBA has included these sites in its repacking exercise and expects to be able to significantly reduce this initial list to less than six sites.

[6] The 150-meter area is designed to ensure that all antennas at a multi-antenna location are protected. It also will allow earth station operators to add antennas on their property without impacting terrestrial operations. Because unregistered antennas are not entitled to protection under the CBA's proposed rules, however, addition of an unregistered antenna cannot extend the 150-meter zone beyond the original boundary of the registered antenna.

PART 27 – MISCELLANEOUS WIRELESS COMMUNICATIONS SERVICES

Create new Section 27.78 to read as follows:

§ 27.78 Protection of FSS earth stations operating in the 3700-4200 MHz band

(a) Registered FSS earth stations. FSS earth stations eligible for the protections described in this section must meet one of the following criteria:

(1) Hold a valid registration to receive satellite signals within the 3700-4200 MHz band filed no later than October 31, 2018;

(2) Hold a valid registration to receive satellite signals within the 3700-4200 MHz band filed during the open filing period from [date 1] to [date 2];

(3) Hold a registration to receive satellite signals within the 3900-4200 MHz band pursuant to a waiver issued with the approval of all flexible use licensees operating within 40 kilometers of the earth station's registered location; or

(4) Hold a license to transmit that also includes the 3700-4200 MHz band.

(b) The reference earth station antenna pattern to be used to calculate the aggregate RF power spectral density ("APSD") limits in this section is as follows:

$G = 52.6$ dBi	for $0° \leq \phi < 1.5°$
$G = 29 - 25 \log \phi$ dBi	for $1.5° \leq \phi < 7°$
$G = 8$ dBi	for $7° \leq \phi < 9.2°$
$G = 32 - 25 \log \phi$ dBi	for $9.2° \leq \phi < 48°$
$G = -10$ dBi	for $48° \leq \phi \leq 180°$

where ϕ is the off-axis angle from the main beam of the antenna in degrees.

(c) Registered earth stations operating consistent with § 2.106 of this chapter are eligible for the following protection.

(1) *Blocking.* The APSD produced in the 3700-3900 MHz band by all base stations operated by a flexible use licensee within 40 kilometers of a registered earth station as measured at the output of a reference RF filter and earth station antenna shall not exceed a value of −81.6 dBm/MHz. This value must be met for

all elevation angles greater than or equal to 5 degrees at the earth station and at any point within a radius of 150 meters from the registered earth station. The flexible use licensee shall calculate the APSD for the specific frequency band in which it is transmitting, using the reference earth station antenna pattern and a reference RF filter, between the feed-horn and low-noise amplifier or low-noise block downconverter ("LNA/LNB"), with an attenuation of 43 dB between 3700 and 3900 MHz.

(2) *Out-of-band emissions into FSS.* The APSD produced in the band 3900-4200 MHz by all base stations operated by a flexible use licensee within 40 kilometers of a registered earth station as measured at the output of a reference RF filter with a 1 dB insertion loss in the passband and earth station antenna shall not exceed a value of −133 dBm/MHz for earth stations used for satellite telemetry, tracking and control ("TT&C") and -128 dBW/MHz for other earth stations. The value must be met for all elevation angles greater than or equal to 5 degrees at the earth station and at any point within a radius of 150 meters from the registered earth station. The flexible use licensee shall calculate the APSD using the reference antenna pattern.

(3) *Co-frequency emissions into FSS operating in 3700-3900 MHz.* The APSD produced in the band 3700-3900 MHz by all base stations operated by a flexible use licensee within 150 kilometers of a registered earth station authorized to operate in the 3700-3900 MHz band as measured at the output of the earth station antenna shall not exceed a value of −133 dBm/MHz for earth stations used for satellite TT&C and -128 dBW/MHz for other operations. This value must be met for all elevation angles greater than or equal to 5 degrees at the earth station and at any point within a radius of 150 meters from the registered earth station. The earth stations authorized to operate in the 3700-3900 MHz band are: [To be provided when the list is finalized]. The flexible use licensee shall calculate the APSD using the reference antenna pattern.

3. Example of Application of the Proposed Rules

This section demonstrates in three steps how the CBA's proposed rules in § 27.78(c)(1) and § 27.78(c)(2) to protect FSS earth stations receiving in the 3900-4200 MHz band would be applied by Flexible Use Licensees using the 3700-3880 MHz band. An example scenario is provided.

Step 1: Identification of base stations

In this hypothetical example, a Flexible Use Licensee wants to deploy the following base stations ("BS") in Boston:

Site	Latitude (°N)	Longitude (°W)	Altitude (m)	Antenna Height (m)
BS_1	42.351240	71.064002	7.50	6
BS_2	42.358536	71.050620	6.70	6
BS_3	42.363673	71.052999	10.35	6

Step 2: Identification of potentially affected earth stations

The Flexible Use Licensee identified the following FSS earth station ("ES") within 40 kilometers of BS_1, BS_2 and BS_3;

Site	Latitude (°N)	Longitude (°W)	Altitude (m)	Antenna Height (m)
ES	42.360100	71.058900	10.4	10

Step 3: Calculation of the aggregate in-band and out-of-band interference generated by proposed base stations

To comply with the rules that the CBA proposes for Commission adoption, the Flexible Use Licensee would assess the aggregate in-band and out-of-band interference generated by each of the base stations identified in Step 1 into the earth station identified in Step 2 because these three proposed base stations are within 40 kilometers of the earth station.

(a) Definition of the protected area

Pursuant to the proposed rules, the protected area for an earth station is the area within 150 meters from the location of the earth station registered in the Commission's International Bureau Filing System. As an illustration, five test sites ("S_n") are used in order to ensure that the levels in the rule are not exceeded over the protected area:

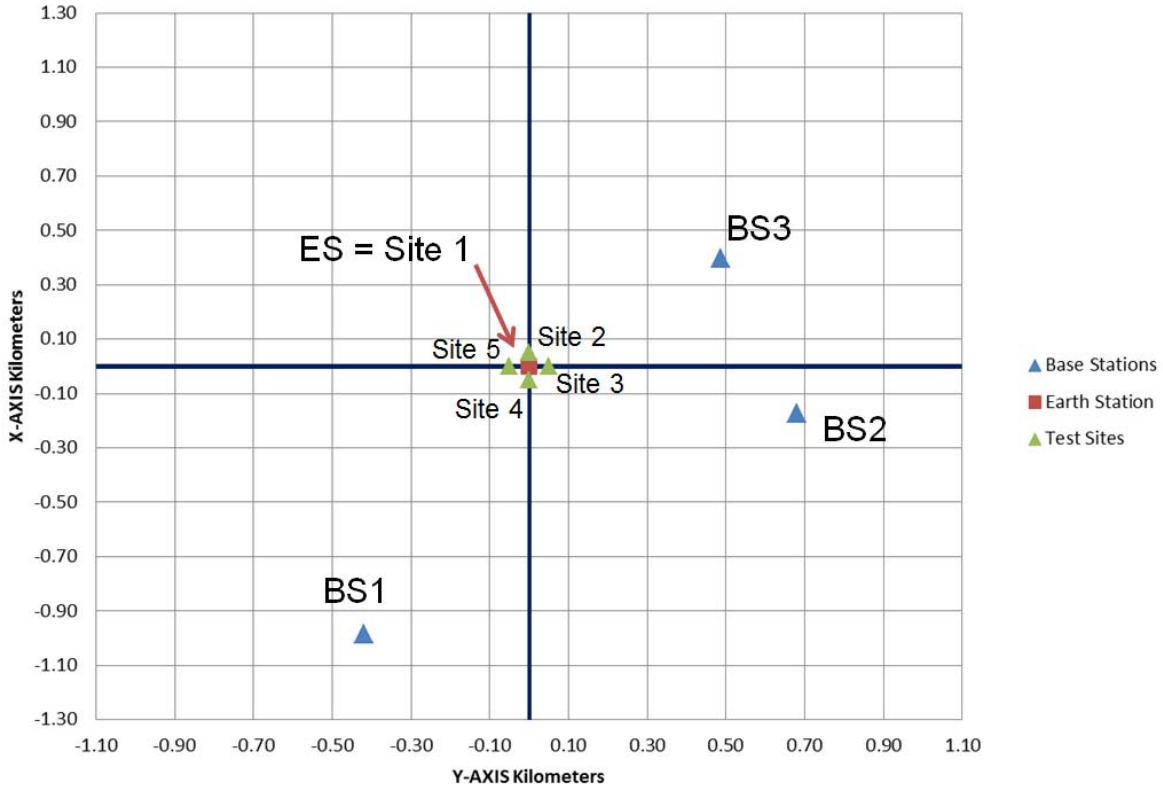
i. S_1: the latitude and longitude of the earth station
ii. S_2: the latitude and longitude of the location 150 meters North of the earth station
iii. S_3: the latitude and longitude of the location 150 meters East of the earth station
iv. S_4: the latitude and longitude of the location 150 meters South of the earth station

v. S_5: the latitude and longitude of the location 150 meters West of the earth station

Note that these locations are used for illustrative purposes and more than five test sites will be required to ensure that all antennas within the protected area are interference free.

Site	Latitude (°N)	Longitude (°W)	Altitude (m)	Antenna Height (m)
S_1	42.360100	71.058900	10.4	10
S_2	42.360549	71.058900	10.4	10
S_3	42.360100	71.058292	10.4	10
S_4	42.359651	71.058900	10.4	10
S_5	42.360100	71.059508	10.4	10

The following diagram shows the location of the FSS earth station ES, the five sites S_1 to S_5, and the three base stations BS_1, BS_2 and BS_3.



(b) Calculation of the In-Band Aggregate Power Density generated in the 3700-3880 MHz band by the base stations identified in Step 1

The In-Band Aggregate Power Density ("IBAPD") generated by the three base stations BS_1, BS_2 and BS_3 into each earth station site is then calculated. An explanation of these calculations is set forth in Appendix A, and the results for the example scenario described herein are shown below. Importantly, as noted in Appendix A, these calculations can easily be performed by means of a software tool developed by the CBA.

	S_1[7]	S_2	S_3	S_4	S_5
$IBPSD_{BS1}$	-126.9	-127.5	-126.7	-126.4	-127.2
$IBPSD_{BS2}$	-126.0	-126.1	-125.4	-125.8	-126.6
$IBPSD_{BS3}$	-95.0	-94.6	-94.4	-95.4	-95.5
IBAPD	-95.0	-94.6	-94.4	-95.4	-95.5
Limit	-81.6 dBm/MHz				
Margin	13.4	13.0	12.8	13.8	13.9

(c) Calculation of the Out-Of-Band Aggregate Power Density generated in the band 3900-4200 MHz by the base stations identified in Step 1

The same process is followed to calculate the Out-of-Band Power Spectral Density ("OBPSD") generated by each base station and the Out-of-Band Aggregate Power Density ("OBAPD") generated by the three base stations into each earth station site.

	S_1[8]	S_2	S_3	S_4	S_5
$OBPSD_{BS1}$	-167.5	-167.8	-167.6	-167.1	-167.3
$OBPSD_{BS2}$	-156.0	-156.1	-155.4	-155.8	-156.6
$OBPSD_{BS3}$	-145.0	-144.6	-144.4	-145.4	-145.5
OBAPD	-144.6	-144.2	-144.1	-145.0	-145.2
Limit	-128 dBm/MHz				
Margin	16.6	16.2	16.1	17.0	17.2

[7] *See* Appendix B for detail of IBAPD calculations for S_1.

[8] *See* Appendix C for detail of OBAPD calculations for S_1.

(d) Comparison of the IBAPD and OBAPD with the values in the rules

The highest IBAPD and highest OBAPD from Step 3 are then compared with the limits in the proposed rules. If the above limits are exceeded, the power produced by BS_1, BS_2 and BS_3 at the earth station can be adjusted to ensure compliance to the proposed rules. In the example scenario there is a positive margin of 12.8 dB for IBAPD and a positive margin of 16.1 dB for OBAPD, which means that base stations BS_1, BS_2 and BS_3 can be deployed as proposed without interfering into the protected area of earth station ES.

4. NCTA Reply Comments

In its *ex parte* submission dated February 8, 2019, NCTA stated that "[r]eallocating a significant portion of the C-band for mobile use would noticeably disrupt television service to hundreds of millions of American consumers unless the Commission takes several enforceable precautions."[9] Specifically, NCTA stated that C-band users must:

- be able to continue operations, with room for growth, technical evolution and back-up capacity;
- be protected from harmful interference from new wirelesses uses that could result in black screens for consumers attempting to view programming;
- be reimbursed for costs incurred in any transition necessary to accommodate new services; [10] and
- be able to change frequencies and repoint antennas on short notice.

In the Comments Technical Annex and Reply Technical Annex, the CBA laid out the interference mechanisms that may affect FSS earth stations when flexible use stations are deployed in the adjacent band. Based on rigorous analyses and testing, the CBA proposed technical rules that would ensure the protection of FSS earth stations, as described above.

Additionally, the CBA specified performance characteristics of pass-band filters to be fitted to every earth station eligible for protection in the United States. The CBA made a clear commitment to deploy more than 100,000 filters at earth stations. This, together with the rules proposed by the CBA, will ensure that all FSS earth stations entitled to protection will be protected from harmful interference from flexible use operations.

In addition, the CBA's proposed rules define a 150-meter radius protected area around each registered FSS earth station and full-band full arc access for any antenna with a

[9] NCTA, *Ex Parte* Letter, GN Docket No. 18-122 (February 8, 2019) at 2.

[10] *Id.* NCTA's requirement that C-band users be reimbursed for transition costs is not technical in nature and is therefore not addressed herein.

diameter between 3 meters and 13 meters. This proposal will provide incumbent FSS earth station owners with ample operational flexibility. The proposed rules also provide a path to add new earth stations in case the already registered earth stations would not be sufficient, so long as the affected Flexible Use Licensee agrees to protect the new earth station. Obtaining agreement from Flexible Use Licensees for a limited number of new earth stations in remote areas where 5G deployment is less intense should be reasonably feasible.

In sum, the rules proposed by the CBA will be enforced by the Commission and are fully in line with what NCTA states is needed from a technical point of view.

5. Comcast Reply Comments and *Ex Parte* Notice

In its Reply Comments and an *ex parte* submission dated February 22, 2019, Comcast raised a number of technical concerns with the CBA's proposal.[11] The concerns Comcast raises have in fact been addressed by the technical elements the CBA included on the record. Nevertheless, to ensure Comcast's understanding, the CBA addresses those concerns again, as set forth below.

In its Reply Comments, Comcast raised the following three concerns,[12] which are all addressed by the CBA's proposed rules:

- *What steps would have to be taken to ensure that C-Band earth stations would not experience harmful interference from mobile devices, particularly given that filters only mitigate and cannot eliminate harmful interference?*

Ensuring the protection of C-band services is the primary objective of the CBA. To achieve this objective, in its Comments Technical Annex the CBA proposed limits on the out-of-band emissions produced by flexible use mobile devices. In the Reply Technical Annex, the CBA also supported "a power limit of 1 Watt and the Commission proposal that mobile and portable stations must employ a means for limiting power to the minimum necessary for successful communications."

- *What alternative arrangements would be available for C-Band operations that filters cannot protect?*

As the CBA has noted, there will be a limited number of TT&C sites that will operate co-frequency/co-coverage with flexible use operations in the 3700-3900 MHz band.

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[11] Reply Comments of Comcast Corporation and NBCUniversal Media, LLC, GN Docket No. 18-122 (December 11, 2018) ("Comcast Reply Comments"); Comcast Corporation, *Ex Parte* Letter, GN Docket No. 18-122 (February 22, 2018 [sic]) at Expanding Flexible Use of the 3.7-4.2 GHz Band Presentation, 3 ("Comcast *Ex Parte*") (describing the CBA's proposal as "A Black Box in Terms of Protecting Incumbents.").

[12] *See* Comcast Reply Comments at 3-4.

Comcast is correct that filters will not protect antennas operating at these limited sites. The CBA has proposed new rule § 27.78(c)(3), set forth above, to ensure protection of these antennas from harmful interference.

- *Would exclusion zones be required to protect C-Band earth stations from adjacent-band mobile operations in a repacked band? If so, how large would they need to be, and how would they be managed and enforced?*

No exclusion zones will be required. The CBA's proposed rules define zones within which aggregate power density limits at the earth station will apply to flexible use operations. These zones are not exclusions zones but, rather, areas within which Flexible Use Licensees will routinely adjust their deployment, if needed, to ensure that earth stations are being protected from harmful interference.

In the Comcast *Ex Parte*,[13] Comcast raised two further concerns which are, again, all addressed by the CBA in its Comments or by the CBA's proposed technical rules:

- *The record remains devoid of rigorous analysis. There is no way to objectively view this record as demonstrating that incumbents will be protected.*

In the Reply Technical Annex, the CBA provided an explanation for every technical element included in its proposed rules.[14] The CBA provides further technical analysis regarding the maximum power at the input of LNB and out-of-band emissions in this *ex parte* submission.

- *Filters do not exist and would not be a panacea if they did. Filters only mitigate interference; they do not prevent it.*

Filters have been used in earth stations to mitigate interference for many decades. Filters designed to address the introduction of flexible use operations exist today. As explained in the Comments Technical Annex: "C-Band Alliance members have already commissioned development of bandpass filters that will adhere to the filter mask, received prototypes, and performed tests to verify that these filters will be capable of suppressing in-band 5G emissions."[15]

Moreover, the CBA has not said that filters alone will solve the problem of protection of C-band earth stations. As explained in the technical material the CBA has submitted on the record and in this notice, it is the combination of the use of filters and

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13 Comcast *Ex Parte* at Expanding Flexible Use of the 3.7-4.2 GHz Band Presentation, 3.

14 Reply Technical Annex at 3, ns. 4-6. *See also id.* at 5-7, ns. 14, 15, 17-19.

15 Comments Technical Annex at 5. Indeed, on September 24, 2018, the CBA conducted a live demonstration of the prototype filter's ability for dozens of Intelsat and SES customers at Intelsat's Ellenwood, Georgia teleport. The CBA would be happy to conduct a similar live demonstration for Comcast in order for their representatives to readily examine and experience the filters firsthand.

implementation of the CBA's proposed rules that will ensure protection of C-band earth stations. The CBA's proposed Section 28.78(c)(1) will protect all earth stations against blocking. Proposed Section 28.78(c)(2) will protect all earth stations against out-of-band emissions from Flexible Use Licensees. Proposed Section 27.78(c)(1) takes into account the characteristics of the filters that will be deployed by the CBA.

6. Maximum Aggregate Power at the Input of LNB

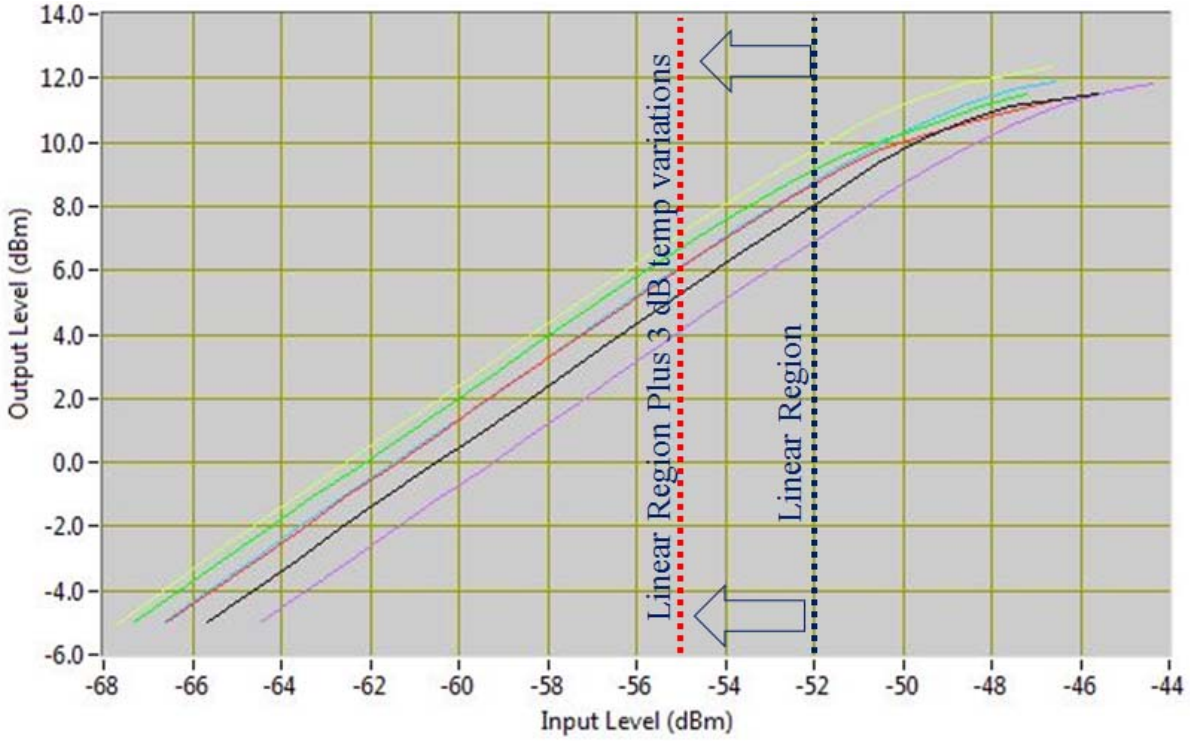
In its Reply Comments, Ericsson criticized the CBA's use of a maximum aggregate power level of -59 dBm at the input of a LNB to protect earth stations against a degradation of the signal. Specifically, Ericsson characterized this level as being "far too conservative for any realistic interference protection regime."[16] In its Comments Technical Annex, the CBA explained that the -59 dBm level was based on performance characteristics of the existing population of fielded LNBs. The CBA also indicated that the -59 dBm level was based on a unit saturation level of -55 dBm, which is a nominal value for most LNBs. Ericsson viewed this 4 dB difference as a "safety margin."[17]

The CBA disagrees with Ericsson's characterization that -59 dBm is "too conservative." The -59 dBm value was determined by the CBA considering the widely deployed high end LNB model 3220 N built by Norsat, as well as other models. Testing conducted for a number of model 3220 N units as shown on Figure 1 demonstrated that for a temperature of 25°C, the maximum input power for the linear region was -52 dBm. A 3 dB factor was then added to account for the change in performance due to temperature variation, leading to a maximum input power of -55 dBm to prevent non-linear distortion during foreseeable operational conditions.

[16] Reply Comments of Ericsson, GN Docket No. 18-122 (December 11, 2018) at 7.

[17] *Id.* at 8.

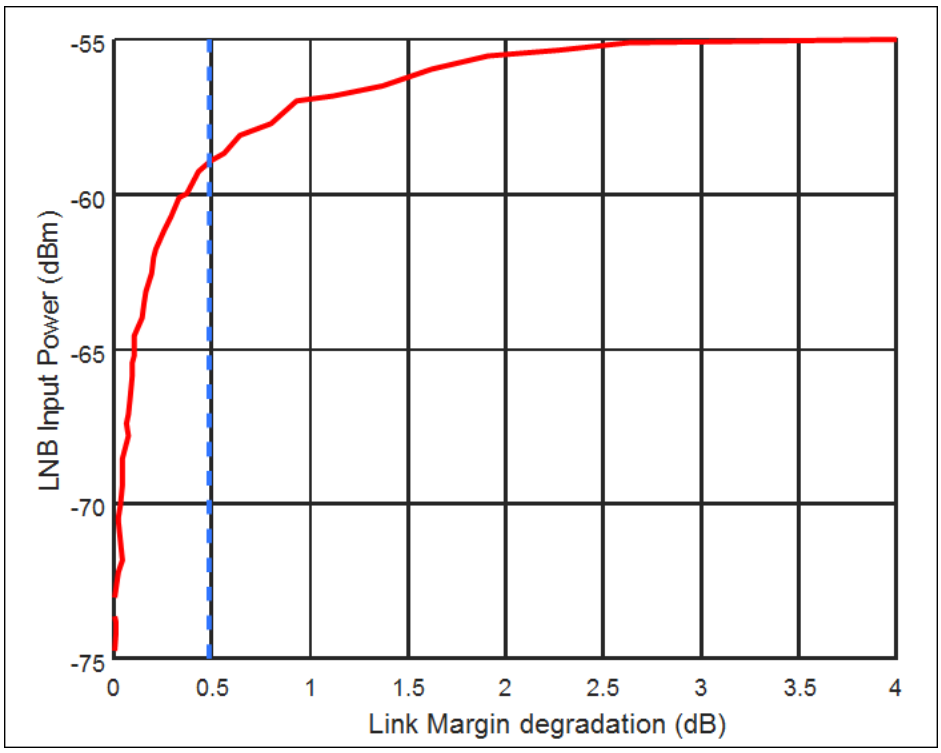
Figure 1



In addition, in order to assess the impact of the significant peak-to-average ratio of terrestrial 5G signals on satellite reception, the CBA performed the following test: a 5G waveform was injected into a representative of the filter that will be deployed by the CBA and the Norsat 3220 N LNB. The input power was decreased starting from -55 dBm.

The CBA determined that a satellite link margin degradation no greater than 0.5 dB was necessary to maintain the high availability required by satellite earth station operators. As shown on Figure 2, a degradation of 0.5 dB was reached with an input power of -59 dBm. The test also showed that at an input power of -75 dBm, the satellite link does not suffer any degradation.

Figure 2



The -59 dBm value must be accounted for over the 180 MHz of 5G operations and was used by the CBA to derive the power density limit of -81.6 dBm/MHz proposed by the CBA in the Reply Technical Annex.

It should also be noted that a similar value, -60 dBm, is set forth in Section 96.17(a)(3) of the FCC's rule, which was adopted by the Commission in April 2016 to protect FSS earth stations operating in the 3600-3700 MHz band from CBRS transmissions. The FCC qualified the -60 dBm value as "a reasonable threshold that would effectively protect many devices but not necessarily the worst case weakest device with the lowest input power limit."[18]

[18] *Commercial Operations in the 3550-3650 MHz Band*, Order on Reconsideration and Second Report and Order, GN Docket No. 12-354, FCC 16-55 (2016) at para. 273.

7. Assessment of the Impact of the Proposed -3 dBm/MHz Out-of-Band Emissions Level

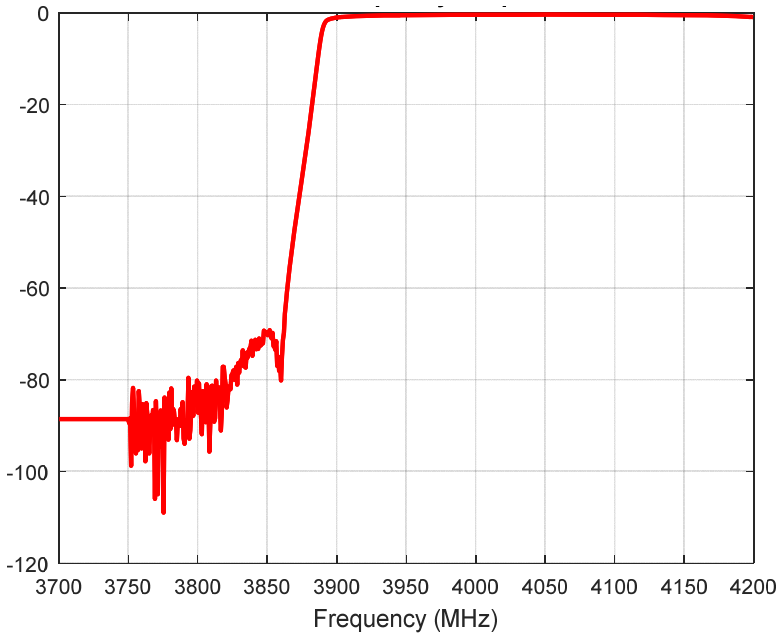
In its Reply Comments, the CBA supported Nokia's revised proposal[19] of conducted power limits for out-of-band emissions: -3 dBm from the band edge to 20 megahertz from band edge, -40 dBm/MHz from 20 megahertz to 40 megahertz from the band edge and -50 dBm/MHz beyond 40 megahertz from the band edge for base stations. AT&T noted in its Reply Comments the -3 dBm value deviates from the -13 dBm/MHz OOBE that are commonplace in other 5G bands.[20]

The CBA's decision to support a value of -3 dBm was based on the following assessment, which demonstrates that an increase of out-of-band emissions from -13 dBm to -3 dBm in the 3880-3900 MHz band has an insignificant impact on satellite reception.

A filter with the characteristics referenced in the Comments Technical Annex (Figure 3) and a 5G waveform with the following out-of-band emission levels (Figure 4) were considered:

-13 dBm/MHz (conductive) from the band edge to 20 megahertz from band edge;
-40 dBm/MHz (conductive) from 20 megahertz to 40 megahertz from the band edge;
-50 dBm/MHz (conductive) beyond 40 megahertz from the band edge.

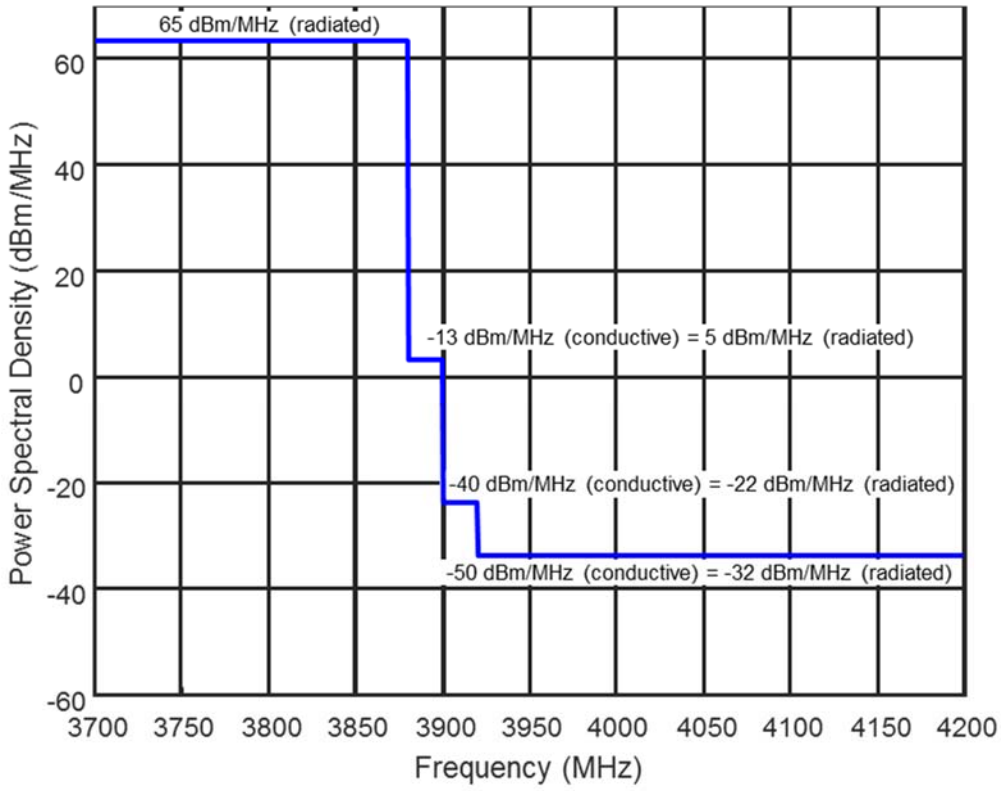
Figure 3: Filter attenuation (dB)



19 *See* Nokia, Correction of Technical Proposal, GN Docket No. 18-122 (December 3, 2018).

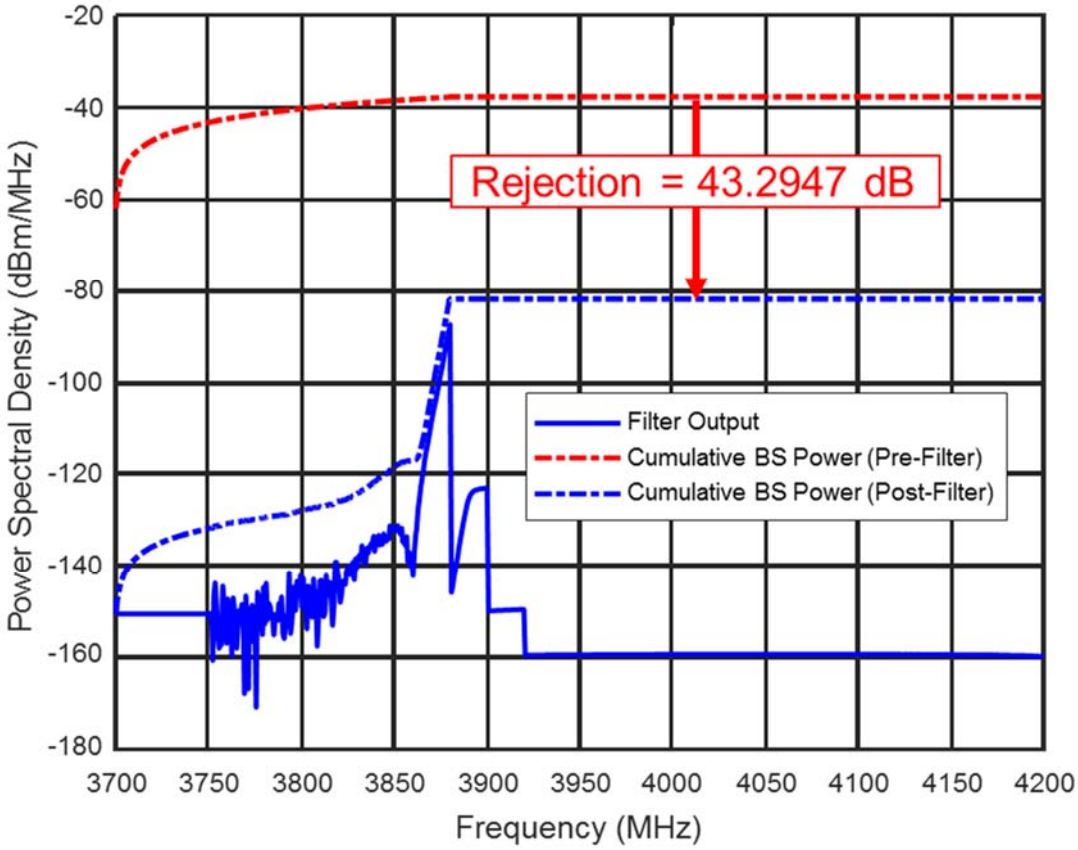
20 AT&T Reply Comments at 24.

Figure 4: 5G waveform



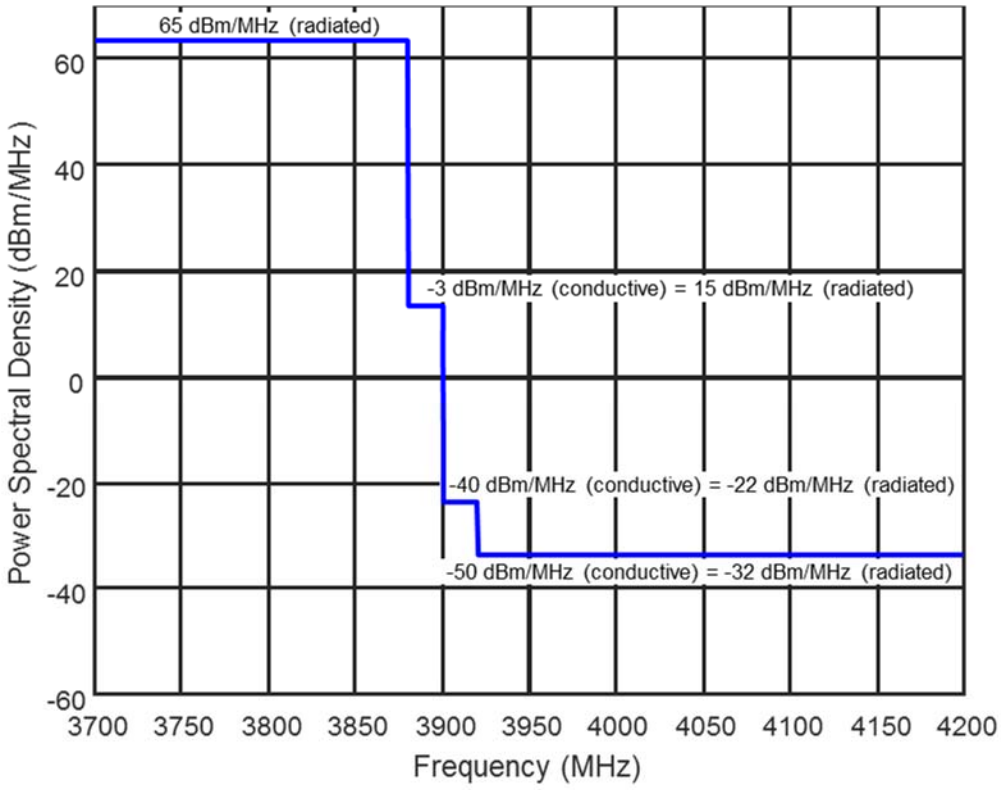
The total power received in the band 3700-3900 MHz at the output of the filter when the 5G waveform is injected at the input of the filter was calculated and compared to the total power of the 5G waveform in the band 3700-3900 MHz at the input to the filter. The difference is the filter rejection, which was calculated to be 43.2947 dB (Figure 5). The value was confirmed by tests performed by the CBA using a prototype filter with the characteristics shown in Figure 3.

Figure 5: filter rejection



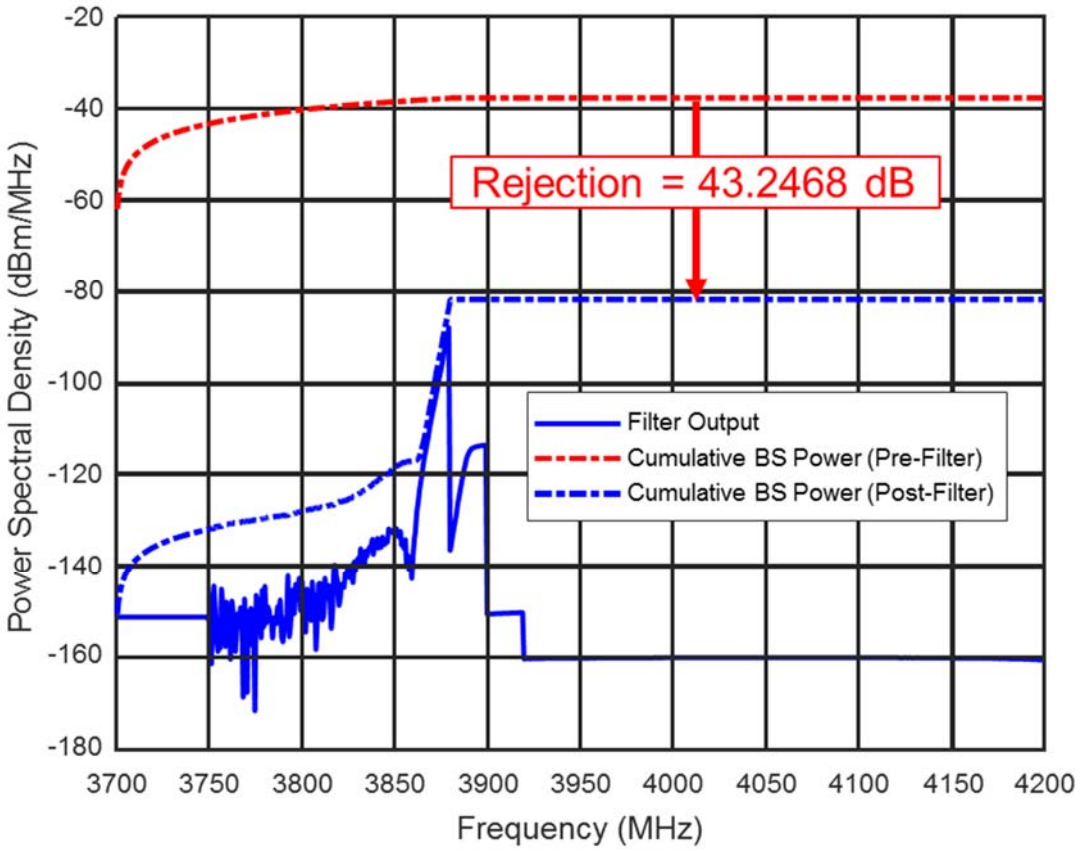
The same calculation was performed assuming a 5G waveform with an out-of-band emission level of -3 dBm/MHz (conductive) instead of -13 dBm/MHz (conductive) in the band 3880-3900 MHz (Figure 6).

Figure 6: 5G waveform



The calculation resulted in a filter rejection of 43.2468 dB Figure 7)

Figure 7: filter rejection



This very small difference is due to the fact that the power spectral density at the output of the filter is only changed over 20 MHz in the 3880-3900 MHz band.

In conclusion, an increase in out-of-band emissions from -13 dBm to -3 dBm in the 3880-3900 MHz band has an insignificant impact on satellite reception.

Appendix A

This appendix describes how to calculate the IBAPD and OBAPD generated by the base stations identified in Step 1 into the earth station identified in Step 2 in order to assess compliance with proposed Section 27.78. These calculations include repetitive steps which can be easily implemented in a software tool. The CBA has developed such a tool and will share it with future Flexible Use Licensees in order to facilitate implementation of the CBA's proposed rules if the CBA's Market-Based Proposal is adopted by the Commission.

A: Path loss and earth station antenna gain

To determine IBAPD and OBAPD it is necessary to (1) determine the path loss between each base station under consideration and the earth station test sites and (2) determine the earth station antenna gain per the CBA-proposed antenna mask in the direction of each base station.

1. Calculate the path losses (PL_{BS1_S1}) between BS_1 and S_1 using the appropriate propagation model.[21]
2. Calculate the angle between a unity vector whose origin is at the S_1 satellite earth station feed and pointing towards the satellite orbital location, for example 87° West, and a unity vector whose origin is at the S_1 satellite earth station feed and pointing towards the antenna of BS_1. We called this the angle of incidence $\phi_{S1\_87°W}$ of the 5G signal into the earth station antenna.
3. Calculate the gain $G_{S1\_87°W}$ of the S_1 earth station antenna towards BS_1 by using the angle of incidence $\phi_{S1\_87°W}$ and the antenna mask specified in the table below.

Antenna Gain	Angle from Boresight
G = 52.6 dBi	for $0° \le \phi < 1.5°$
G = 29 - 25 log ϕ dBi	for $1.5° \le \phi < 7°$
G = 8 dBi	for $7° \le \phi < 9.2°$
G = 32 - 25 log ϕ dBi	for $9.2° \le \phi < 48°$

[21] The CBA proposes that all mobile operators use the same propagation model to perform this assessment. The CBA is assessing which propagation model is the most appropriate considering the distances and the accuracy needed.

G = -10 dBi	for 48° ≤ ϕ ≤ 180°

4. Repeat steps (A1) to (A3) for base stations BS_2, BS_3 and sites S_2, S_3, S_4 and S_5.

B: IBAPD calculation

1. Calculate the In-Band Power Spectral Density (IBPSD) of the signal generated by BS_1 and received at the output of a reference filter on the satellite earth station antenna on S_1 by using the following formula, assuming all values are in dB

$$IBPSD_{BS1\_S1\_87°W} = EIRPD_{BS1\_S1} – PL_{BS1\_S1} + G_{S1\_87°W} - F$$

Where $EIRPD_{BS1\_S1}$ is the Effective Isotropic Radiated Power Density (EIRPD) radiated from BS_1 in the direction of S_1 and F is the 43 dB filter rejection of the 5G IBPSD.

2. Repeat step (B1) for orbital locations 105°W and 139°W to calculate $IBPSD_{BS1\_S1\_105°W}$ and $IBPSD_{BS1\_S1\_139°W}$. Select the higher value of $IBPSD_{BS1\_S1\_87°W}$, $IBPSD_{BS1\_S1\_105°W}$, $IBPSD_{BS1\_S1\_139°W}$. This value is $IBPSD_{BS1\_S1.}$ Note that according the CBA-proposed rules, all orbital locations for which the elevation is greater than 5 degrees must be assessed; this example uses only the three locations of 87°W. 105°W and 139°W for illustrative purposes.
3. Repeat steps (B1) and (B2) for base stations BS_2 and BS_3 to calculate $IBPSD_{BS2\_S1}$ and $IBPSD_{BS3\_S1.}$
4. Calculate the $IBAPD_{S1}$ into S_1 from all three base stations BS_1, BS_2, and BS_3. Assuming $IBPSD_{BS1\_S1}$, $IBPSD_{BS2\_S1}$, and $IBPSD_{BS3\_S1}$ are in dBs, use the following formula:

$$IBAPD_{S1} = 10 * LOG10 \left(10^{(IBPSDBS1\_S1/10)} + 10^{(IBPSDBS2\_S1/10)} + 10^{(IBPSDBS3\_S1/10)}\right)$$

5. Repeat steps (B1) to (B4) to generate the IBAPD of the remaining four sites (S_2, S_3, S_4, and S_5): $IBAPD_{S2}$, $IBAPD_{S3}$, $IBAPD_{S4}$, and $IBAPD_{S5}$.
6. Select the highest value of $IBAPD_{S1}$, $IBAPD_{S2}$, $IBAPD_{S3}$, $IBAPD_{S4}$, and $IBAPD_{S5}$. This value is the IBAPD for the protected area of earth station ES.

C: OBAPD calculation

1. Determine the maximum base station transmit antenna gain of BS_1 in the direction of S_1 (G_{BS1_S1}) and any cable and coupling losses (L_{BS1}) between the transmitter and the antenna at BS_1.

2. Calculate the Out-Of-Band Power Spectral Density ($OBPSD_{BS1\_S1}$) of the signal generated by BS_1 and received at the output of a reference filter on the satellite earth station antenna at S_1 by using the following formula:

$$OBPSD_{BS1\_S1\_87°W} = OBPD_{BS1} – L_{BS1} + G_{BS1\_S1} – PL_{BS1\_S1} + G_{S1\_87°W} - F$$

   Where F is the 1 dB filter attenuation of the 5G OBPSD and $OBPD_{BS1\_S1}$ is the conductive Out-of-Band Power Density generated by BS_1 above 3900 MHz. If the OBPD is not constant above 3900 MHz, select the highest value.
3. Repeat steps (C1) and (C2) for base stations BS_2 and BS_3 to calculate $OBPSD_{BS2\_S1\_87°W}$ and $OBPSD_{BS3\_S1\_87°W}$.
4. Repeat step (C2) for orbital locations 105°W and 139°W to calculate $OBPSD_{BS1\_S1\_105°W}$ and $OBPSD_{BS1\_S1\_139°W}$. Select the higher value of $OBPSD_{BS1\_S1\_87°W}$, $OBPSD_{BS1\_S1\_105°W}$, $OBPSD_{BS1\_S1\_139°W}$. This value is $OBPSD_{BS1\_S1}$. Note that according the CBA's proposed rules, all orbital locations for which the elevation is greater than 5 degrees must be assessed; this example uses only the three locations of 87°W. 105°W and 139°W for illustrative purposes.
5. Calculate the Out-of-Band Aggregate Power Density ($OBAPD_{S1}$) into S_1 from all three base stations BS_1, BS_2, and BS_3. Assuming $OBPSD_{BS1\_S1}$, $OBPSD_{BS2\_S1}$, and $OBPSD_{BS3\_S1}$ are in dBs, use the following formula:

$$OBAPD_{S1} = 10 * LOG10 (10^{(OBPSDBS1\_S1/10)} + 10^{(OBPSDBS2\_S1/10)} + 10^{(OBPSDBS3\_S1/10)})$$

6. Repeat steps (C1) to (C5) to generate the OBAPD of the remaining four sites (S_2, S_3, S_4, and S_5): $OBAPD_{S2}$, $OBAPD_{S3}$, $OBAPD_{S4}$, and $OBAPD_{S5}$.
7. Select the highest value of $OBAPD_{S1}$, $OBAPD_{S2}$, $OBAPD_{S3}$, $OBAPD_{S4}$, and $OBAPD_{S5}$. This value is the OBAPD for the protected area of earth station ES.

Appendix B

IBAPD calculations for S_1

Site 1 In-Band Calculations				
Parameter	**BS1**	**BS2**	**BS3**	**Units**
Base Station EIRP	50	40	60	dBm/MHz
Angle of Incidence	39.15	97.43	134.68	Degrees
Base Station Antenna Discrimination	-22	-12	-2	dB
Distance	1071.76	702.95	627.48	Meters
Path Losses	-104.64	-100.98	-99.99	dB
Orbital Location	87	87	87	degrees West
ES Antenna Gain	-7.82	-10.00	-10.00	dBi
ES Filter Rejection	-43.00	-43.00	-43.00	dB
IBPSD	-127.46	-125.98	-94.99	dBm/MHz
IBAPD Total 87W	-94.98			dBm/MHz
Base Station EIRP	50	40	60	dBm/MHz
Angle of Incidence	37.35	116.70	150.12	Degrees
Base Station Antenna Discrimination	-22	-12	-2	dB
Distance	1071.76	702.95	627.48	Meters
Path Losses	-104.64	-100.98	-99.99	dB
Orbital Location	105	105	105	degrees West
ES Antenna Gain	-7.3064	-10	-10	dBi
ES Filter Rejection	-43.00	-43.00	-43.00	dB
IBPSD	-126.95	-125.98	-94.99	dBm/MHz
IBAPD Total 105W	-94.98			dBm/MHz
Base Station EIRP	50	40	60	dBm/MHz
Angle of Incidence	52.18	149.80	155.13	Degrees
Base Station Antenna Discrimination	-22	-12	-2	dB
Distance	1071.76	702.95	627.48	Meters
Path Losses	-104.64	-100.98	-99.99	dB
Orbital Location	139	139	139	degrees West
ES Antenna Gain	-10	-10	-10	dBi
ES Filter Rejection	-43.00	-43.00	-43.00	dB
IBPSD	-129.64	-125.98	-94.99	dBm/MHz
IBAPD Total 139W	-94.98			dBm/MHz

Appendix C

OBAPD calculations for S_1

Site 1 Out-of-Band Calculations				
Parameter	**BS1**	**BS2**	**BS3**	**Units**
Base Station PSD	-50	-50	-50	dBm/MHz
Angle of Incidence	39.15	97.43	134.68	Degrees
Base Station Antenna Gain	18.00	18.00	18.00	dBi
Base Station Antenna Discrimination	-22	-12	-2	dB
Distance	1071.76	702.95	627.48	Meters
Path Losses	-104.64	-100.98	-99.99	dB
Orbital Location	87	87	87	degrees West
ES Antenna Gain	-7.82	-10.00	-10.00	dBi
ES Filter Attenuation	-1.00	-1.00	-1.00	dB
OBSPD	-167.46	-155.98	-144.99	dBm/MHz
OBAPD Total 87W	-144.63			dBm/MHz
Base Station PSD	-50	-50	-50	dBm/MHz
Angle of Incidence	37.35	116.70	150.12	Degrees
Base Station Antenna Gain	18.00	18.00	18.00	dBi
Base Station Antenna Discrimination	-22	-12	-2	dB
Distance	1071.76	702.95	627.48	Meters
Path Losses	-104.64	-100.98	-99.99	dB
Orbital Location	105	105	105	degrees West
ES Antenna Gain	-7.3064	-10	-10	dBi
ES Filter Attenuation	-1.00	-1.00	-1.00	dB
OBSPD	-166.95	-155.98	-144.99	dBm/MHz
OBAPD Total 105W	-144.63			dBm/MHz
Base Station PSD	-50	-50	-50	dBm/MHz
Angle of Incidence	52.18	149.80	155.13	degrees
Base Station Antenna Gain	18.00	18.00	18.00	dBi
Base Station Antenna Discrimination	-22	-12	-2	dB
Distance	1071.76	702.95	627.48	meters
Path Losses	-104.64	-100.98	-99.99	dB
Orbital Location	139	139	139	degrees West
ES Antenna Gain	-10	-10	-10	dBi
ES Filter Attenuation	-1.00	-1.00	-1.00	dB
OBSPD	-169.64	-155.98	-144.99	dBm/MHz
OBAPD Total 139W	-144.64			dBm/MHz